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A REVIEW OF LAND SURFACE TEMPERATURE AND HUMIDITY CONDITIONS SPECIFIED FOR AUSTRALIA IN DEF (AUST) 5168 AND STANAG 2895

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L.M. Barrington

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Abstract

Australian Ordnance Council (AOC) Task 154 "Definition of the Australian Environmental Conditions Affecting the Design of Military Materiel" was accepted by the Explosives Environmental and Service Life Advisory Committee (EESLAC) in 1990 to provide a concise definition of the possible manufacture to target environments to which materiel designed for the ADF could be exposed. This task was divided into two discrete areas of work by EESLAC, namely a study of surface transport vibration levels and a comparative analysis of available meteorological data and the contents of DEF (AUST) 5168. This paper discusses the latter analysis, expanded to include a review of STANAG 2895 also.

In general, the available data suggests that the operational and storage diurnal cycles defined in the two standards reasonably represent the conditions likely to be experienced in Australia. However. the effects of direct solar radiation on materiel must also be considered in determining the maximum temperature which the materiel surface is likely to attain.

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A Review of Land Surface Temperature and Humidity Conditions Specified for Australia in DEF (AUST) 5168 and STANAG 2895

1. *Introduction*

The climatic environmental conditions which military materiel could encounter in operations and storage throughout the world have been considered by the ABCA nations and resulted in a Quadripartite Standardisation Agreement QSTAG 360 'Climatic Factors Affecting the Design of Military Materiel', issued in 1979 to replace QSTAG 200. The promulgation of this agreement led to a major revision of Australia's DEF (AUST) 168 'Climatic Extremes for Service Equipment'. A revised Australian Defence Standard was issued in 1982 as DEF (AUST) 5168 'The Climatic Environmental Conditions Affecting the Design of Military Materiel' [1], which superseded DEF (AUST) 168 and is the Australian implementation of QSTAG 360. Some climatic factors encountered in northern Australia were shown to be more severe than the comparable QSTAG 360 conditions and DEF (AUST) 5168 included this additional data accumulated in Australia.

QSTAG 360 was also adopted by NATO and issued as STANAG 2831. This STANAG in turn was superseded in 1990 by STANAG 2895 'Extreme Climatic Conditions and Derived Conditions for use in Defining Design/Test Criteria for NATO Forces Materiel' [2].

The validity of the data contained in Part 1 (Ground Operations) of DEF (AUST) 5168 and in STANAG 2895 (hereafter referred to collectively as 'the two standards') has been questioned as it pertains to Australian climatic conditions, and this paper compares some available Australian temperature and humidity data with the information specified in the two standards.

No other climatic factors (eg wind, hail, rain, sand etc) are considered.

2. *Differences Between DEF (AUST) 5168 and STANAG 2895*

2.1 *Definitions*

In both standards, two temperatures or conditions are defined. The first is:

> "the ambient air temperature measured under standard conditions of ventilation and radiation shielding in a meteorological screen at a height of 1.2 to 2.0 m above the ground".

This is defined as the 'operational temperature' in DEF (AUST) 5168, and the 'meteorological temperature' in STANAG 2895. For convenience, this condition is referred to as the 'operational' condition for the remainder of this paper.

The second definition is:

> "the air temperature (and humidity in the STANAG) measured inside a temporary unventilated field storage shelter which is exposed to direct solar radiation. This condition would be found, for example, under tarpaulin covers or in a railway van".

This is defined as the 'storage temperature' in DEF (AUST) 5168, and the 'storage and transit conditions' in STANAG 2895 (hereafter the 'storage' condition).

Further, both standards acknowledge that when assessing the *maximum* temperature attained by materiel, the incidence of direct solar radiation upon the materiel must be taken into account. The thermal response of materiel to this radiation will depend to an appreciable extent upon its thermal mass and surface finish. For precise values in individual instances, field trials or accurate simulations are essential.

By considering these definitions it is clear which two scenarios the two standards are describing. The terms 'storage' or 'storage and transit' refer to field storage under makeshift or temporary unventilated shelters, and land transport in enclosed or tarpaulin covered vehicles. Air temperatures within these enclosures may well exceed ambient conditions, however the materiel itself is not exposed to direct solar radiation, only the enclosure. The 'operational' or 'meteorological' condition describes only the ambient meteorological conditions measured as described above, and may have little relationship to conditions actually experienced by the materiel at time of use or operation. Thus the climatic environment which the materiel will experience during this phase will be ambient (standard meteorological) conditions, plus any increase in temperature due to direct solar radiation on the item itself. This may in fact more resemble 'storage' conditions if the materiel is deployed inside a vehicle. Depending on the magnitude of direct solar radiation then, the materiel surface or skin temperature in the operational condition may or may not exceed its temperature in a field storage configuration. This is discussed further in Section 6.

Neither standard discusses any conditions applicable to magazine storage, or any phase of the materiel life prior to field deployment and subsequent field

storage. Presumably, this is based on the reasonable assumption that magazine storage conditions are never as severe as field storage or operational conditions.

2.2 *Climatic Categories*

According to DEF (AUST) 5168:

> "To facilitate the discussion of ambient air temperatures and humidities, twelve climatic categories have been chosen to represent the distinctive types of climate to be found throughout the world, excluding Antarctica. Eight of these (termed A1, A2, C0, C0(A), C1, C2, C3 and C4) are defined with temperature as the principal consideration while the remaining four (termed B1, B1(A), B2 and B3) represent climates in which high humidity accompanied by a relatively high temperature is the outstanding characteristic" [1].

STANAG 2895 defines eleven climatic categories referring to the land surfaces, consistent with the DEF (AUST) 5168 categories but with the following exceptions: it does not discuss categories C0(A) or B1(A) which are based on Australian data in DEF (AUST) 5168, but includes an additional category A3.

DEF (AUST) 5168 also states:

> "Unless otherwise specified in the requirements document, military materiel for the Australian Defence Forces will be designed to remain safe and be capable of acceptable performance when subjected to the operational and storage temperature, humidity and solar radiation conditions of categories A2, B1(A), B2 and C0." [1].

These latter four categories are discussed in detail below. In each category, DEF (AUST) 5168 presents temperature and humidity data in the form of diurnal cycles, for both the operational and storage conditions. STANAG 2895 gives the same diurnal cycles, however it also includes plots of the number of days and hours in the year that temperatures attain or exceed a given value.

3. *Category A2 - Intermediate Hot Dry*

3.1 *Description*

Category A2 incorporates "areas which experience high temperature accompanied by high levels of solar radiation and moderately low relative humidities, viz, southern Europe, the Australian continent, ...". [1], [2].

DEF (AUST) 5168 also states:

> "Although the whole of Australia is classified as category A2 in Figure I only the shaded region in Figure II [Figure 1 of this paper] experiences temperature conditions which are close to those defining category A2. Over the remainder of the continent, except in coastal altitudes over 1000 m, days with diurnal cycles close to that of category A2 will occur but the average time during which temperatures are above 44°C will be less than 7.4 hours in the hottest month. Temperatures close to those of category A2 will not occur in Tasmania." [1].

Figure 1(A) of STANAG 2895 shows Australia divided into categories A2 and A3. The region described as category A2 includes almost all of the 'shaded region in Figure II' from DEF (AUST) 5168, as well as all of the northern coast of Australia, as shown in Figure 1. The remainder of the continent is classed as category A3. The STANAG does emphasise that the areas to which these categories apply are shown only approximately, they are not intended to indicate that the climate at each and every location complies exactly with the diurnal cycles given, and that these areas should be used as a guide for a particular item of materiel to determine its required climatic design and performance criteria.

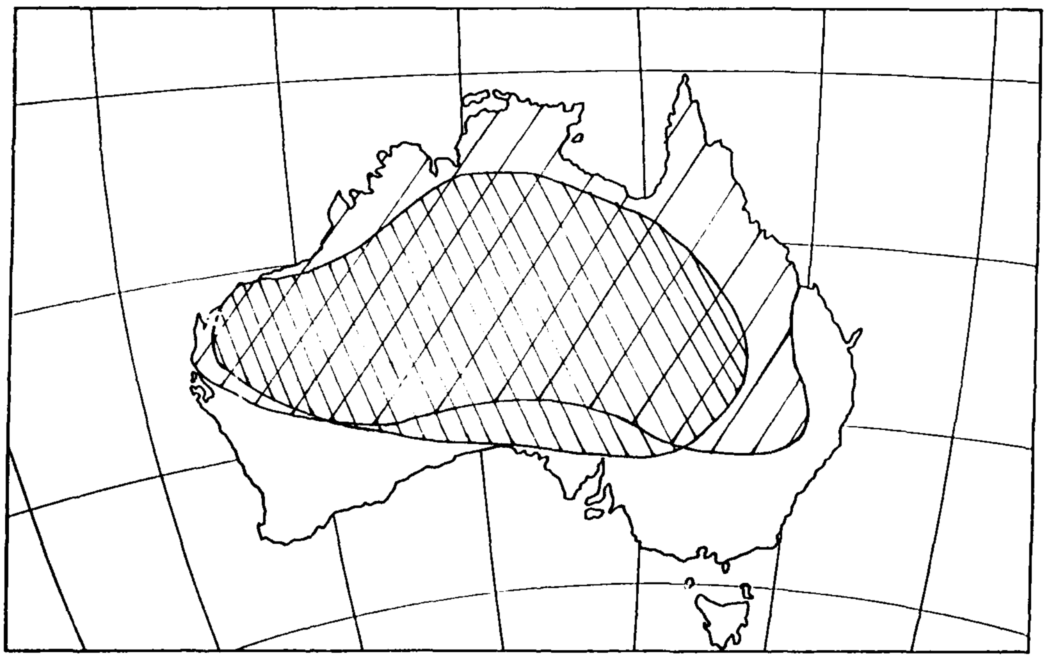

Figure 1: *Areas of Australia experiencing category A2 conditions, according to DEF(AUST) 5168 [1] and STANAG 2895 [2].* *Conditions close to Category A2 [1];* *Category A2 [2].*

Noting that category A3 is less severe than A2, both standards essentially state that materiel for use in Australia must be safe and capable of acceptable performance when subjected to category A2 conditions, and that these conditions occur over a very large area of the Australian continent.

3.2 *Operational Conditions*

The highest temperature of the A2 operational temperature cycle equates to that air temperature, measured in a meteorological screen, which was attained or exceeded at the hotter locations in the category, on average, for a total time of approximately 7.4 hours (ie 1% of one month) during the hottest month [1]/ period [2] of the year. The profile of the cycle is typical of those days when this temperature is just attained. The cycle is defined from observations made in the western United States which border the deserts and the Australian desert regions.

Note that there is a discrepancy in the way the highest temperature above is defined between the two standards: DEF (AUST) 5168 uses '7.4 hours during the hottest *month*', while STANAG 2895 quotes '7.4 hours during the hottest *period*', and yet they both give the same diurnal cycle. It is known that the earliest versions of these diurnal cycles were based on 'a total of 7.4 hours during the hottest period of the year', hence it is suggested that the DEF (AUST) 5168 cycle is actually based on 7.4 hours during the hottest period, not month. Theoretically, a cycle based on 7.4 hours during the hottest period may have a slightly higher 'highest temperature' as there may be days in the months either side of the hottest month where the temperature will be close to the highest temperature recorded in the hottest month. However, it is reasonable to assume that the differences in cycles using either definition are insignificant in comparison to the actual variations within any category.

1% temperatures and corresponding diurnal temperature cycles have been compiled from Australian meteorological data in references [3] and [4]. In particular, 'High Temperatures in Australia' by Redman and McRae [4] provides an excellent analysis of the 'high temperature' diurnal cycles which occur in Australia. As their primary data, Redman and McRae used three-hourly temperature and humidity records for 33 stations across Australia for a ten year period (1963 - 1972). This data was supplied on magnetic tape by the Bureau of Meteorology. From these records, they obtained the 1% temperature at each location for each month (the temperature that was reached or exceeded on average for 7.5 hours in that month over the ten year period). The corresponding 1% diurnal temperature cycles for the hottest month (defined as the month with the highest 1% temperature) were then obtained by averaging the three-hourly temperatures recorded on all days when the 1% temperature was reached or exceeded. Note that these cycles calculated by Redman and McRae are based on the '1% during the hottest month' definition, which as discussed in the paragraph above is not the criterion on which the cycles in the two standards have been based, however the differences can be assumed to be very small.

From this data, the 'hottest' 1% diurnal cycle in Australia occurs at Oodnadatta. This three-hourly temperature cycle, together with that of the two standards, is reproduced in Table 1 below.

Table 1: *1% Diurnal Cycles - Oodnadatta and DEF (AUST) 5168/STANAC 2895 – A2 Operational Conditions*

Local Time	Oodnadatta Temp (°C)	The Two Standards (°C)
0300	31.9	32
0600	30.2	30
0900	37.0	37
1200	42.7	42
1500	44.5	44
1800	42.7	42
2100	38.3	36
2400	35.1	33

From this Table, it is evident that there is very little difference between the cycles at Oodnadatta and that of the two standards, with both showing the same maximum and minimum temperatures and the former being only slightly more severe in the intervening time periods.

Redman and McRae found a range of 1% diurnal cycles across Australia. The 'hottest' of these ranges of cycles and the area in which it occurs is reproduced from [4] in Figure 2. The area identified in Figure 2 closely represents the area described by the two standards as resembling category A2 operational conditions, excepting for the northern coast of Australia in STANAG 2895. Redman and McRae found that this entire area of Australia can be covered by a 1% diurnal cycle having a temperature band width of only approximately 4°C, with the Oodnadatta cycle being the upper limit of this range. This finding provides very strong support for the A2 operational cycle of the two standards. In fact, Redman and McRae's findings reported in 1975 [4] were presumably used to revise DEF (AUST) 168 into DEF (AUST) 5168 in 1982:

> "... The work here was done as part of a program to relate the Australian mainland climate to the nominated climatic categories of QSTAG 360 and also provide data for the revision of DEF (AUST) 168". [4].

A point which is emphasised in [4]:

> "... these conclusions are based only on the data used this study. From other data [5] it would appear that the hottest area in Australia is probably the Simpson Desert, but there are no detailed figures available for this area. Moomba (29°S, 140°E) is reported to have an 86 percentile daily maximum (once a week) of 46.6°C in December against the corresponding temperature of 43.0°C for Oodnadatta [5]. Similarly average daily maximum temperatures for Marree, Birdsville, Boulia and Finke indicate that they also experience higher temperatures than Oodnadatta [5]."

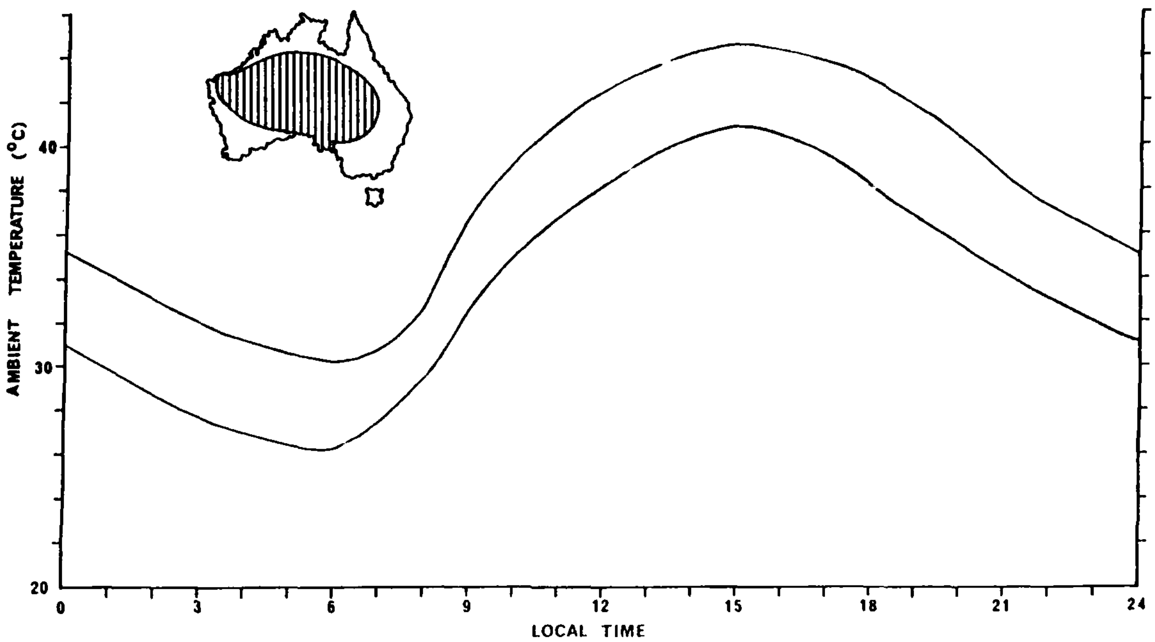

Figure 2: Range of A2 operational diurnal cycles occurring in the shaded area [4].

In addition to the above diurnal temperature cycle, STANAG 2895 also gives plots of the number of days per year and number of hours per year for which, on average, a given temperature is just attained or exceeded. Data for the 'number of days per year' plot is obtained from the 5 to 10 percent climatically least hospitable regions of the category: this plot shows approximately four days per year where, on average, the maximum temperature exceeds 44°C. The 'number of hours per year' plot is *computed* from the 'number of days per year' results and the above diurnal cycle, and shows 7.4 hours per year where, on average, the maximum temperature exceeds 44°C. This value of 7.4 hours per year is consistent with the STANAG definition of the highest temperature of the A2 operational temperature cycle being based on 7.4 hours in the hottest *period* of the year. STANAG 2895 then states that this plot may be used to devise cycles with, for example, a 5 or 10 percent criterion rather than the more severe 1 percent criterion defined above, for equipment where lower confidence levels are acceptable. The STANAG does recommend that for explosives, propellants and pyrotechnics, temperature and humidity levels should be based on the 1 percent criterion, which is the A2 operational cycle given in Table 1 above.

For comparison with STANAG 2895, Webb [6] describes the results of storage trials on an empty S280 communications shelter and four manpack radios, exposed at Cloncurry for the period 1 November 1985 to 24 January 1987. Cloncurry is situated at latitude 20°40' south, longitude 140°30' east, and as such is within the area designated by the two standards as experiencing category A2 conditions. Of particular interest, ambient air temperatures were recorded every 15 minutes. Table 2 below, compiled from [6], gives the number of hours and number of days in the period December 1985 to November 1986 that a given ambient air temperature was just attained or exceeded.

Table 2: *Ambient air temperature data – S280 communications shelter trial at Cloncurry [6]*

Temp (°C)	Number of Hours Temp was exceeded	Number of Days Temp was exceeded
46.4 max	0.25	1
46	0.5	1
45	4.25	3
44	17.75	12
42	162.25	44
40	474	99
35	1844	198
30	3766.5	268
25	5703.5	319
20	7069.75	342
10	8202.75	
6.1 min	8280	

Notwithstanding the fact that these results cover one specific twelve month period only, the ambient air temperature attained or exceeded 45°C for only 4.25 hours and 44°C for 17.75 hours. Comparing temperatures for this twelve month period with similar measurements taken over eight years, Webb [6] concluded that ambient temperatures over this specific period were only approximately 0.5° to 1.5°C higher than for an average year. These results then provide good support for the operational 1% temperature of 44°C given in Table 1, and for the range of diurnal cycles discussed in [4]. Reference [6] also contains plots of the number of hours (and days) in the period for Cloncurry and for the A2 operational condition (from [2]) that a given ambient air temperature is just attained or exceeded. These plots are reproduced in Figures 3 and 4. Values for Cloncurry are also adjusted for instrumentation errors and screen effects. These Figures show reasonable agreement with the STANAG results at the highest temperatures, however below that the conditions at Cloncurry are more severe for longer periods than the STANAG suggests.

As to humidity, QSTAG 360 states that the likely water vapour pressure will be between 12 and 25 mb with a diurnal range of less than 2 mb. DEF (AUST) 5168 goes further to state that Australian data indicates that vapour pressures as low as 5 mb are likely, that the diurnal range can be up to 15 mb and where water vapour pressure is a critical design parameter the Australian values should be used or further information obtained. STANAG 2895 gives a diurnal cycle for relative humidity with the A2 operational condition, which ranges from 14 to 44 percent.

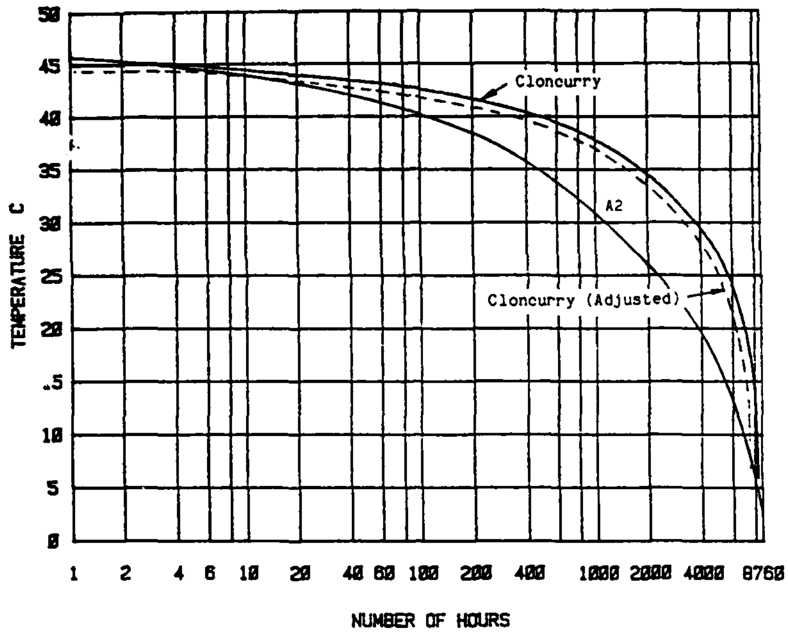

Figure 3: *Number of hours in the period for Cloncurry and for the A2 operational condition that a given ambient air temperature is just attained or exceeded [6].*

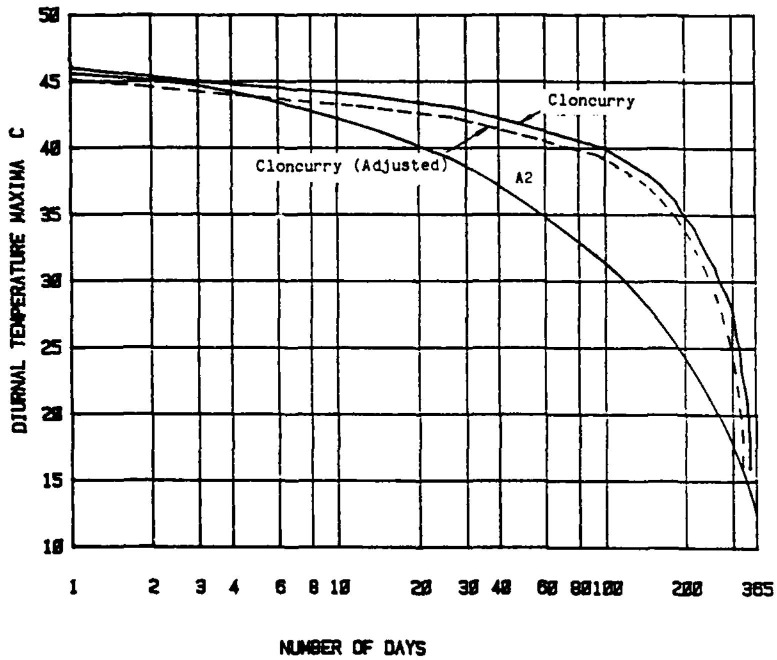

Figure 4: *Number of days in the period for Cloncurry and for the A2 operational condition that a given ambient air temperature is just attained or exceeded [6].*

Information compiled by the Bureau of Meteorology [5] gives twice-daily mean relative humidities for each month, for each of its stations across Australia. From these mean values, it is not possible to accurately construct a diurnal cycle. In 1980, Murrell and McRae [7] provided a summary of climatic conditions at 19 locations across Australia for the RAAF. Included in their report is a summary of the extreme absolute humidities likely to be experienced in each season for all 19 stations. Their findings include many seasons at many locations where the mean maximum humidity exceeds 30 mb. Similarly, many mean minimum humidities of less than 5 mb occur. No data relevant to the diurnal range is given.

3.3 *Storage Conditions*

The same A2 storage cycle is given in DEF (AUST) 5168 and STANAG 2895. The exact source of this cycle is not defined, except to say that it is based on measurements inside a temporary unventilated field storage shelter exposed to direct solar radiation [1] and based on a similar criterion (ie 1 percent) to the A2 operational cycle [2]. The temperature component of this cycle is reproduced in three-hourly form from [1] and [2] in Table 3 below.

Table 3: *1% Diurnal cycle - DEF (AUST) 5168/STANAG 2895 – A2 storage conditions*

Local Time	Temperature (°C)
0300	32
0600	31
0900	42
1200	57
1500	63
1800	57
2100	38
2400	33

A number of references which describe field trials at the Cloncurry site of the Tr' pical Science Branch, Scientific Services Division, MRL, DSTO - Queensland, formerly the Joint Tropical Trials and Research Establishment (JTTRE), have been examined for comparison with the A2 storage cycle in Table 3 above.

In many of these references (for example [8]), the maximum operational and storage temperatures recorded were grossly below the upper limits of this category and so these references were not considered further.

In his study of the S280 communications shelter, Webb [6] discusses the internal shelter air temperature which was measured halfway along the west side of the shelter at 75 percent of shelter height. These results are considered very apt for comparison with the Table 3 conditions as the S280 in this study is effectively a 'temporary, unventilated field storage shelter exposed to direct solar radiation'. Table 4 below, compiled from [6], gives the number of hours and the number of days in the period December 1985 to November 1986 that a given internal air temperature at 75% height of the S280 shelter was just attained or exceeded.

Table 4: Storage temperature data – S280 communications shelter at Cloncurry [6]

Temp (°C)	Number of Hours Temp was exceeded	Number of Days Temp was exceeded
60.8 max	0.25	1
60	1.75	1
59	5.5	5
58	12.5	10
57	38.75	42
56	84.25	68
54	210.5	112
52	418.5	169
50	709.75	250
45	1560.75	302
40	2343.75	328
30	4302.75	341
20	6884	346
10	8076.75	
3.3 min	8280	

Again, these results are based on one specific twelve month period only, however ambient air temperatures during this period were shown to reasonably approximate the category A2 operational conditions, and hence these storage conditions can be reasonably compared to the category A2 storage conditions. Table 4 shows that a shelter internal air temperature of 59°C was attained or exceeded for only 5.5 hours and 58°C for 12.5 hours in the twelve month period considered. These results provide some support for the 1% storage-temperature of 63°C as defined in the two standards. Although not reproduced here, the plots of number of hours and number of days that a given internal air temperature at 75% of shelter height was just attained [6] agrees well with the STANAG plots for category A2 storage conditions. The STANAG conditions are more severe at the higher temperatures, but fall away faster than the Cloncurry results, as was the case with the A2 operational condition.

Information of further interest was provided by RAAF [9]. This consisted of 1988 to February 1991 Explosives Ordnance Facility Temperature and Humidity Records for four Buildings (580, 583, 584 and 585) at Tindal. From [9] "these Records probably represent worse case conditions given the recent and future planned upgrades to EO storage facilities at both Tindal and Darwin ... The future plans for Tindal should see a number of 7 Bar Spantech type earth-covered igloos constructed for EO storage ... a number of these facilities have already been constructed at Darwin ...". These records indicate that temperatures in these buildings are much less severe than category A2 storage conditions, however they are frequently more severe than A2 operational temperature conditions. Buildings 580 and 583 are traversed carports having an unvented ISO container installed. Building 584 is a traversed light frangible building also having an unvented ISO container installed while Building 585 is a ventilated light frangible shed. The

records are not complete, with weekend and unit stand down figures missing, however from the information available for the 30 month period, as a minimum:

i. In Buildings 580 and 583, the daily maximum temperature attained or exceeded 45°C on 252 and 290 days respectively. The highest daily maximum recorded was 56°C in Building 583.

ii. In Building 584, the daily maximum temperature attained or exceeded 40°C on 67 days. The highest daily maximum recorded was 43°C.

iii. In Building 585, the daily maximum temperature attained or exceeded 40°C on 64 days. The highest daily maximum recorded was 42°C.

The contrast between Buildings 580 and 583 with 584 and 585 is stark, and strongly supports the need for the improved storage facilities at Tindal which are planned [9].

For humidity with the A2 storage cycle, DEF (AUST) 5168 reiterates the comments made concerning water vapour pressures for the A2 operational condition, while STANAG 2895 states that humidities vary too widely between different situations to be represented by a single set of conditions. No relevant humidity data from field trials was located for comparison.

4. Categories B1 - Wet Warm, B1(A) - Wet Warm, Australia and B2 - Wet Hot

4.1 Description

The B1 (Wet Warm) category in both standards applies to "those areas which experience moderately high temperatures accompanied by continuous very high relative humidity. These conditions are found in rain forests and other tropical regions during periods of continuous cloud cover where direct solar radiation is not a significant factor." [1], [2].

STANAG 2895 does not contain a B1(A) (Wet Warm, Australia) category: this category is defined in DEF (AUST) 5168 to cover nominally the same areas as category B1. According to DEF (AUST) 5168, although the B1(A) figures are not yet internationally accepted, they are more severe than those quoted in the B1 cycles and are closer to actual conditions experienced in Australia.

The B2 (Wet Hot) category in both standards includes "areas which experience moderately high temperatures accompanied by high humidity and high direct solar radiation. These conditions occur in the exposed areas of the wet tropical regions named in category B1 (read also B1(A))." [1], [2].

According to the world maps given in both standards, there are two areas of Australia which experience category B1(A) [1]/ B1 [2] and B2 conditions. From these maps, these two areas can be approximately described by the regions:

i. everywhere north of approximately latitude 13°S, and

ii. everywhere north-east of an approximate line from St Lawrence to Edward River, Queensland.

4.2 Operational Conditions

The B1(A) cycles for the operational condition are derived from data collected under the rain forest canopy in Northern Queensland [1]. The B1 and B2 cycles for the operational condition are derived from observations made in Singapore and at the Gulf of Mexico coastal stations respectively, and subsequently confirmed by observations in other tropical areas [1],[2].

The 1% diurnal cycles for the B1, B1(A) and B2 operational conditions are reproduced in three-hourly form from the two standards in the following table:

Table 5: *1% Diurnal cycles - DEF (AUST) 5168/STANAG 2895 – B1, B1(A) and B2 operational conditions*

Local Time	B1 Cycles[1]		B1(A) Cycles		B2 Cycles	
	Temp (°C)	Rel H (%)	Temp (°C)	Rel H (%)	Temp (°C)	Rel H (%)
0300	23	88	25	100	26	100
0600	23	88	24	100	26	100
0900	28	76	25	100	31	82
1200	31	66	28	95	34	75
1500	32	67	28	95	35	74
1800	29	75	26	100	32	82
2100	26	84	25	100	28	95
2400	24	88	25	100	27	100

Note 1: STANAG 2895 states that this B1 cycle applies for 358 days per year, while for the other 7 days the temperature is nearly constant at 24°C and the relative humidity is nearly constant at 100% throughout the 24 hours of each day. For category B1, DEF (AUST) 5168 gives only one cycle where the temperature is nearly constant at 24°C and the relative humidity varies from 95% to 100%.

Considering the area of Australia which has been designated categories B1/ B1(A) and B2, four of the locations considered in [4] lie within this area. 1% diurnal temperature cycles for the 'hottest' months at these locations (Darwin, Thursday Island, Cairns and Townsville) are reproduced from [4] in Table 6 below.

Table 6: *1% Diurnal temperature cycles - Darwin, Thursday Island, Cairns and Townsville [4]*

Local Time	Darwin Temp (°C)	Thursday Island Temp (°C)	Cairns Temp (°C)	Townsville Temp (°C)
0300	26.5	27.4	25.9	27.5
0600	15.7[1]	27.1	25.4	25.6
0900	29.1	29.9	31.1	31.4
1200	32.9	31.0	35.4	35.0
1500	35.1	31.8	33.0	35.0
1800	31.6	29.9	30.6	32.2
2100	29.3	28.5	28.4	29.3
2400	27.6	27.9	28.2	28.4

Note 1: It is presumed that the value for 0600 at Darwin is a typographical error in [4] and should read 25.7°C, not 15.7°C.

These diurnal temperature cycles correlate very well with the B2 temperature cycle specified in the two standards.

In the same manner as Cloncurry was compared to category A2 operational conditions in STANAG 2895, Webb [6] also describes the results of storage trials on the same S280 communications shelter and four manpack radios, exposed at Innisfail for the period 1 October 1984 to 30 September 1985. Innisfail is in a high rainfall coastal region of Northern Queensland at a latitude of 17°30' south and is within the area designated by the two standards as experiencing category B1/B1(A) and B2 conditions. Again, ambient air temperatures were recorded every 15 minutes during this trial. Table 7 below, compiled from [6], gives the number of hours and number of days in the period October 1984 to September 1985 that a given ambient air temperature was just attained or exceeded.

Table 7: *Ambient air temperature data – S280 communications shelter trial at Innisfail [6]*

Temp (°C)	Number of Hours Temp was Exceeded	Number of Days Temp was Exceeded
40.8 max	0.25	1
40	3.25	1
39	5.25	1
38	7.75	2
37	9.5	3
36	14.5	6
34	50.5	15
32	257	66
30	730.25	133
25	3286.25	294
20	7107.25	364
9.7 min	8713	

Acknowledging that these results cover one specific twelve month period only, the ambient air temperature attained or exceeded 37°C for 9.5 hours and 35°C for approximately 28 hours. Comparing temperatures for this twelve month period with similar measurements taken over eight years, Webb [6] concluded that ambient temperatures over this specific period were again approximately 0.5° to 1.5°C higher than for an average year, so that these results provide some support for the operational 1% temperature of 35°C as given in Table 5. Reference [6] also contains plots of the number of hours (and days) in the period for Innisfail and for the B2 operational condition (from [2]) that a given ambient air temperature is just attained or exceeded. These plots are reproduced in Figures 5 and 6. Values for Innisfail are also adjusted for instrumentation errors and screen effects. These figures show the opposite trend to what was observed for Cloncurry and category A2. Figure 5 in particular shows conditions at Innisfail to be significantly hotter than the STANAG suggests at the highest temperatures, but the Innisfail temperatures fall away faster than the STANAG.

As Webb [6] notes, Figure 19 of Annex D to STANAG 2895 is in error. This is the plot reproduced from the STANAG [2] by Webb [6] and shown here in Figure 5. This curve shows a peak temperature of 34°C, whereas the peak temperature in the 'number of days' B2 curve is 35.5°C (see Figure 6) with there being three days at or above 35°C. This error is further confirmed by the B2 diurnal cycle which shows a two hour period at 35°C and a total of five of the twenty four hours at or above 34°C. This error makes the difference in Figure 5 between Innisfail conditions and the STANAG appear slightly larger than is in fact the case.

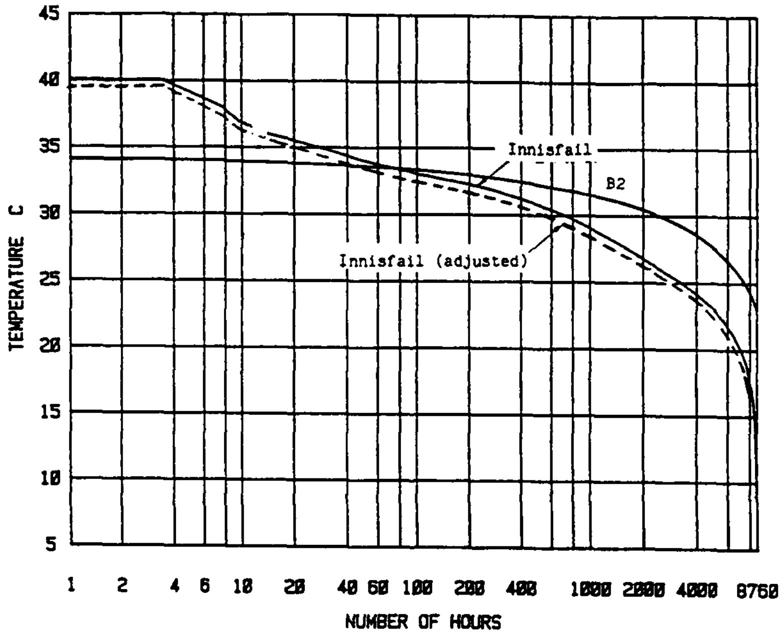

Figure 5: Number of hours in the period for Innisfail and for the B2 operational condition that a given ambient air temperature is just attained or exceeded [6].

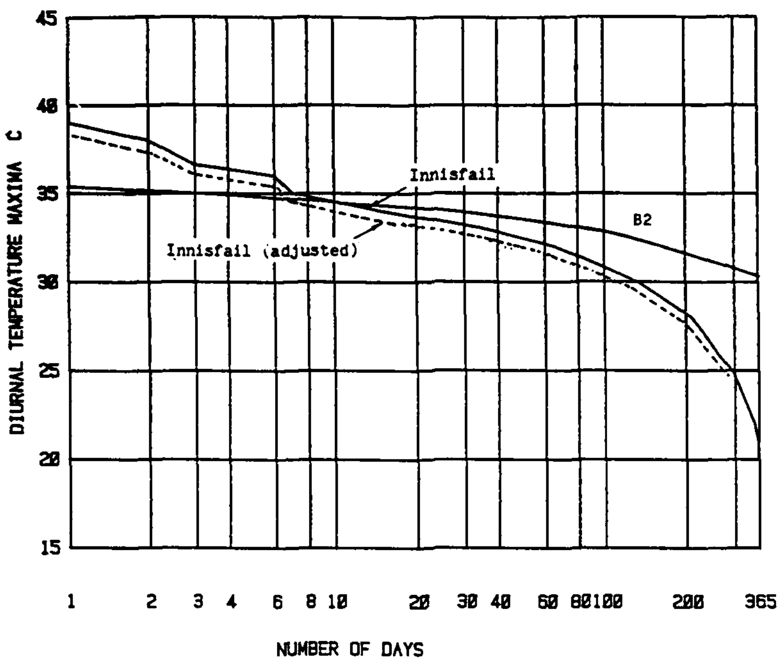

__Figure 6:__ Number of days in the period for Innisfail and for the B2 operational condition that a given ambient air temperature is just attained or exceeded [6].

Relative humidity data for direct comparison (ie a 'diurnal humidity cycle' which occurs with the associated 1% diurnal temperature cycle) is not available in any of the references cited. Relative humidity information which is available in [5] includes the 9 am and 3 pm mean relative humidities for each month, for each location. According to [5], conventional practice is to use the 9 am mean relative humidity as the mean for any given day. Accepting that, Table 8 below lists the mean relative humidities for the 'hottest' month, as well as the maximum mean relative humidity and the month in which it occurs, for each location in Table 6:

__Table 8:__ 9 am Mean relative humidities - Darwin, Thursday Island, Cairns and Townsville

Location	Mean 9 am RH - 'Hottest' Month (%)	Highest 'Mean 9 am RH' and Month in which it Occurs (%)
Darwin	73 - Nov	83 - Feb
Thursday Island	77 - Dec	86 - Feb
Cairns	73 - Jan	79 - Mar
Townsville	71 - Jan	75 - Feb

From this table, the highest mean 9 am relative humidities vary from 75% to 86% within these four locations: this compares favourably with the category B2 figure for relative humidity at 9 am (82%) shown in Table 5. While some daily maximum relative humidities will be higher than the mean values quoted in Table 8, the two standards specify approximately 9 hours per diurnal cycle at 100% relative humidity for category B2 conditions and a minimum relative humidity in the cycle of 74% which seems sufficiently severe.

No meteorological data is available for comparison with the B1 / B1(A) cycles as they were derived from data collected under the rain forest canopies in Singapore and Northern Queensland respectively, and no reference to the latter data source is given in DEF (AUST) 5168 to check its validity. As stated earlier, according to DEF (AUST) 5168 the B1(A) figures are more severe than those quoted in the B1 cycle. This allegation was true at the time of issue of DEF (AUST) 5168 when the B1 cycle in QSTAG 360 consisted entirely of 24 hours at 24°C and relative humidity varying from 95% to 100%. The B1 cycle in STANAG 2895 however is now based on 7 days of saturation at 24°C, and 358 days per year of lower relative humidities but significantly higher temperatures, as shown in Table 5. It now becomes a matter of judgement as to whether the B1(A) cycle [1] or the B1 [2] cycle is considered more appropriate for Australia.

The following is proposed: given that military materiel for use in Australia should be designed to remain safe and be capable of acceptable performance under B2 conditions, and from Table 5 these conditions of temperature and humidity are more severe than the '358 days per year' component of the B1 cycle, it is suggested that the '358 days per year' requirement of category B1 has already been satisfied. It thus remains to design and test based on either the 7 days of saturation at 24°C [2] or the B1(A) cycle of DEF (AUST) 5168. As the latter has allegedly been generated from data collected in Northern Queensland, and is the more severe of the two, its use is recommended. In effect, the category B1 requirements of STANAG 2895 are satisfied by the category B2 cycle and the B1(A) cycle of DEF (AUST) 5168.

4.3 Storage Conditions

For categories B1 and B1(A), the two standards give the same diurnal cycles for the storage conditions as for the operational conditions on the basis that any direct solar radiation is negligible in these categories.

In the two standards, the storage temperatures for category B2 have been defined as equal to those for the A2 storage conditions, taking into account the relatively high ambient air temperatures and direct solar radiation which can occur in regions covered by this category on days when clear skies prevail. In calculating the relative humidities for the storage conditions, the standards assume that the dew points for each hour quoted are the same as those for the corresponding operational conditions.

The B1, B1(A) and B2 storage conditions are reproduced from [1] and [2] in Table 9 below.

Table 9: *1% Diurnal cycles - DEF (AUST) 5168/STANAG 2895 – B1, B1(A) and B2 storage conditions*

Local Time	B1 Cycle[1]		B1(A) Cycle		B2 Cycle	
	Temp (°C)	Rel H (%)	Temp (°C)	Rel H (%)	Temp (°C)	Rel H (%)
0300	23	88	25	100	32	71
0600	23	88	24	100	31	75
0900	28	76	25	100	42	43
1200	31	66	28	95	57	22
1500	32	67	28	95	63	19
1800	29	75	26	100	57	22
2100	26	84	25	100	38	54
2400	24	88	25	100	33	68

Note 1: STANAG 2895 states that this B1 cycle applies for 358 days per year, while for the other 7 days the temperature is nearly constant at 24°C and the relative humidity is nearly constant at 100% throughout the 24 hours of each day. For category B1, DEF (AUST) 5168 gives only one cycle where the temperature is nearly constant at 24°C and the relative humidity varies from 95% to 100%.

No data has been located for comparison with the B1 or B1(A) storage cycles, however the storage cycles are put equal to the operational cycles, which seems reasonable because of the negligible effect of solar radiation in these categories. Hence, no additional testing is required for category B1 or B1(A) storage conditions.

For category B2 storage conditions, Webb [6] discusses the S280 communications shelter internal air temperature which was measured halfway along the west side of the shelter at 75 percent of shelter height during the twelve month trial period at Innisfail. Table 10 below, compiled from [6], gives the number of hours and the number of days in the period October 1984 to September 1985 that a given internal air temperature at 75 percent height of the S280 shelter was just attained or exceeded.

Table 10: *Storage temperature data – S280 communications shelter at Innisfail [6]*

Temp (°C)	Number of Hours Temp is exceeded	Number of Days Temp is exceeded
54 max	0.5	1
53	2	1
52	5.5	3
51	11.5	8
50	26.25	13
48	97.75	35
46	273.5	70
44	502	101
40	1041.75	173
35	1813.5	262
30	2826.5	323
20	7230.5	364
10	8692	
8.4 min	8713	

These results show a shelter internal air temperature of 52°C which was attained or exceeded for only 5.5 hours and 51°C for 11.5 hours in the twelve month period considered. This table suggests that during periods when the ambient temperatures closely represent the operational conditions of category B2 (see discussion after Table 7), storage temperatures at Innisfail may be significantly less severe than the storage temperatures of category B2. This result is not surprising when considering that the storage temperatures for category B2 are defined as the same as for category A2. Noting that the solar radiation and air temperatures are both lower for B2 operational conditions than for A2 operational conditions, then B2 storage temperatures should be lower than A2 storage temperatures.

The plots of number of hours and number of days that a given internal air temperature at 75 percent of shelter height was just attained [6] are not reproduced here: they show that the STANAG conditions are significantly more severe until the extreme lower temperatures where the STANAG falls away faster than the Innisfail results. This is the opposite trend to what was observed for the B2 operational conditions.

As to humidity, no trials data was located where humidity measurements had been made under storage conditions for a direct comparison with the B2 humidity cycle from the two standards. In the absence of data, the assumption of dew points being the same for storage as for operational conditions is a reasonable approach.

5. Categories C0 - Mild Cold and C0(A) - Mild Cold, Australia

5.1 Description

Category C0 (Mild Cold) covers "areas which experience mildly low temperatures such as the coastal areas of western Europe under prevailing maritime influence and parts of New Zealand." [1], [2].

According to DEF (AUST) 5168, the conditions of climatic category C0 are internationally accepted and should be used as design criteria unless overriding factors dictate to the contrary, for example, when designing materiel for use only in Australian conditions, in which case a category C0(A) (Mild Cold, Australia) is defined. It is less severe than C0 conditions.

5.2 Operational Conditions

The C0 (Mild Cold) temperature cycle for the operational condition is "derived from observations made at the coldest 10% European locations of the C0 category. The lowest temperature of this cycle equates to that air temperature, measured in meteorological screens which, on average, was attained or exceeded for all but approximately 7.4 hours (ie 1% of a month) during the coldest month [1]/ period [2] of the year." [1], [2].

The C0(A) cycle is a mild cold cycle derived from Australian data [1]. The lowest temperatures occurring in Australia are experienced in isolated areas above 1500 m and the conditions encountered in these areas are not representative of a significant region. The diurnal cycle given is based on a 1% temperature of -6°C and is typical of conditions likely to be encountered in the colder parts of the area shown in Figure 7 [1].

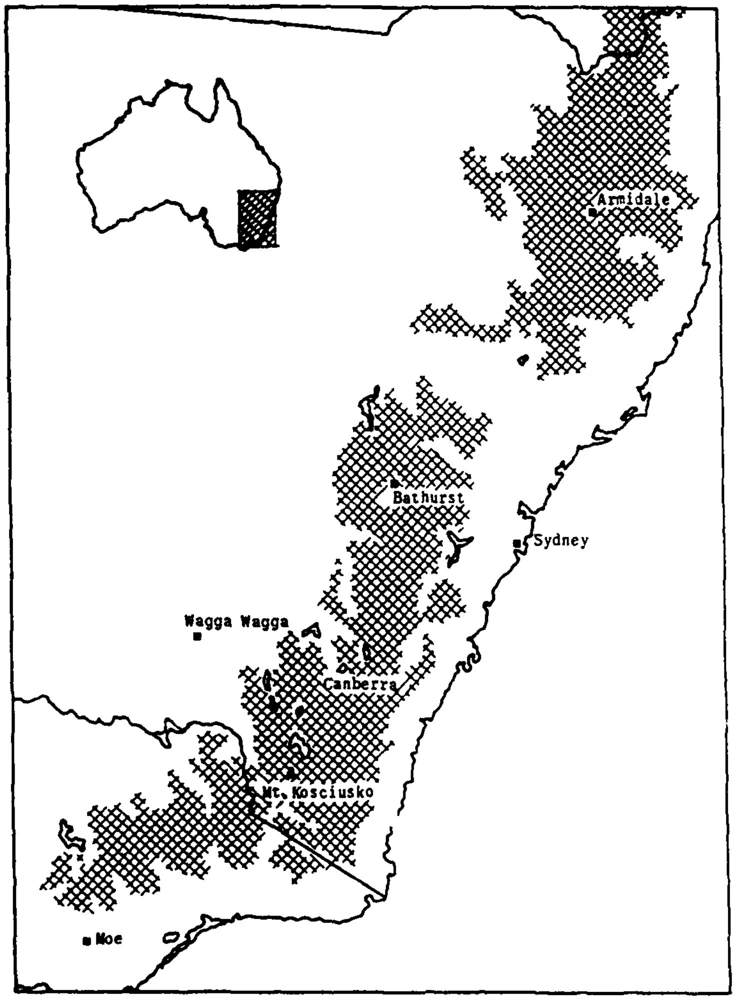

Figure 7: Area of Australia experiencing category C0(A) conditions, according to DEF (AUST) 5168 [1].

The 1% diurnal temperature cycles for the operational conditions of categories C0 and C0(A) are reproduced in three hourly form from the two standards in Table 11 below.

Table 11: *1% Diurnal cycles - DEF (AUST) 5168/STANAG 2895 – C0 and C0(A) operational conditions*

Local Time	C0 Temperature (°C)	C0(A) Temperature (°C)
0300	-19	-4
0600	-19	-6
0900	-15	-2
1200	-8	8
1500	-6	11
1800	-10	7
2100	-17	2
2400	-19	-1

No detailed study of low temperature Australian data was found in any of the literature, so some available Bureau of Meteorology data [5] has been evaluated here.

Low temperature data from three locations, Bathurst, Canberra and Kiandra, has been considered: they are all in the shaded area of Figure 7 and are all at elevations less than 1500 m (713 m, 571 m and 1395 m respectively). While reference [5] does not give 1% high or low temperatures, it does give 14 percentiles of daily minimum and daily maximum temperatures, for each month at each location. The 14 percentile of daily maxima is that temperature which was not attained or exceeded on 14 percent of days (about one day in seven, or on average, one day per week). The 14 percentile of daily minima is that value below which the temperature falls on 14 percent of days (about one day in seven, or on average, one day per week). From [5], these 14 percentiles for the coldest month at each of the three locations above are given in Table 12:

Table 12: *14 Percentiles - Bathurst, Canberra and Kiandra*

Location	Coldest Month	14 Percentile of Daily Min (°C)	14 Percentile of Daily Max (°C)
Bathurst	July	-4.4	7.8
Canberra	July	-4.6	8.7
Kiandra	July	-11.1	1.0

If a diurnal cycle for each location was formed based on the 14 percentiles as upper and lower temperature limits, then these cycles could be interpreted as: on average, one day per week the minimum temperature is below the lower limit of the cycle, and on average, one day per week the maximum temperature is above the upper limit of the cycle.

From Tables 11 and 12, the '14 percentile cycles' for Bathurst and Canberra compare very well with the C0(A) cycle of [1] at the lower limit of the cycle, and not quite so well at the upper limit. While the Kiandra cycle is significantly more severe than C0(A), it is much less severe than C0, confirming that C0 conditions would only be approached in the higher parts of the Australian alps.

Aside from the area in Figure 7, the remainder of the Australian mainland sees low temperatures which are much less severe than those of the C0(A) cycle. As to Tasmania, according to DEF (AUST) 5168:

> "Night temperatures similar to those of ... (the C0(A) cycle) ... but with lower daytime temperatures can be expected in isolated areas of Tasmania with altitudes greater than 400 m."

This is supported by the data in [5] which shows that throughout Tasmania, daily minima are greater than -6°C, although daily maxima in the coldest month frequently do not reach 11°C over a large portion of the island.

Given the lack of low temperature data available for Australian conditions, no comments can be offered concerning the STANAG plots of number of hours and number of days per year on which, on average, a given minimum temperature is not exceeded.

With regard to humidity, as a result of a lack of data, both standards note the relative humidities as tending to saturation for category C0. Considering that low temperature is the principal consideration in categories C0 and C0(A), this is considered to be acceptable.

5.3 *Storage Conditions*

The storage temperatures for category C0 are lower than the corresponding operational temperatures as storage shelters are often better radiators to the night skies than either the ambient air or the ground [1], [2].

However, for category C0(A) "storage temperatures are not known under these conditions but it should be noted that in this area cold conditions are normally experienced with clear skies and that, unlike the C0 cycle, solar radiation will not be negligible between 0800 and 1600 hours. For this reason, storage temperatures can be expected to be higher than operational temperatures for some part of the diurnal cycle" [1].

The two standards give a storage cycle for category C0 which ranges from -10°C to -21°C. No cycle is given for category C0(A), however the above paragraph and the C0 storage cycle indicate that a C0(A) storage cycle would be very similar to the C0(A) operational cycle, with only a slightly lower minimum (perhaps 2°C lower) and a slightly higher maximum (perhaps 2°C higher).

No references were found for trials of Australian military materiel being stored at any temperatures close to the operational conditions of category C0(A). However, the assertions made concerning the similarities between storage and operational cycles are reasonable and materiel designed for use only in Australian conditions should only be subjected to the C0(A) operational diurnal cycle, to satisfy both operational and storage condition requirements.

6. *The "Added" Effect of Solar Radiation*

Both the storage and operational conditions described in the two standards refer to *air* temperatures. The storage condition is intended to allow for the effect of solar radiation impinging on an unventilated enclosure, but not directly on the materiel. As mentioned in Section 2.1, when assessing the maximum temperature attained by *directly exposed materiel*, the incidence of direct solar radiation on the materiel must be taken into account. The temperature rise above the relevant operational temperature on the surface of an item exposed to solar radiation is proportional to the intensity of the incident radiation. The constant of proportionality is a function of a number of factors, two of which are surface finish which determines the amount of energy absorbed and the heat transfer from the exposed surface to the interior of the item.

A number of trials in which items were exposed in the open air in areas of Australia described by Category A2 have recorded materiel surface temperatures in excess of those experienced in unventilated enclosures.

During Webbs' S280 communications shelter trial at Cloncurry [6], a number of manpack radios were exposed on concrete aprons close to the S280 communications shelter. On each radio, temperatures were recorded at the centre of the outside surface of each large face and internally on a suitable component in the centre of each radio. While the maximum internal radio temperature which was recorded was 60.6°C (for 0.25 hours in the twelve month period), the maximum radio surface temperature recorded was 66.1°C. The radio surface temperature exceeded 60°C for 117 hours and 63°C for 10.25 hours in the twelve month period.

Further trials results which show high materiel surface temperatures are given in [10] and [11]. These both refer to a trial conducted for 57 days from 27 November 1981 to 21 January 1982 at Macrossan Depot, 12 km east of Charters Towers. The trial involved three Cartridges, 105 mm Tank, HESH L35A3 which each had four thermocouples fitted to them. Charters Towers is situated at latitude 20°5' south, longitude 146°16' east, and during the period involved the maximum ambient temperatures recorded were approximately 4°C below the A2 operational cycle. The three Cartridges were each painted a different colour (one black, one olive and one white) and their exposure was changed periodically from full exposure to solar radiation ('exposed') to shaded from direct solar radiation by a tarpaulin with an air gap between the tarpaulin and the cartridges ('shaded') to completely covered by a tarpaulin in direct contact with the cartridges ('covered').

Results reproduced from [11] in Table 13 below show the 22 occasions on which component temperatures in excess of 65°C were recorded during the 57 day exposure period.

Table 13: *Materiel temperature data – 105 mm tank Hesh ammunition at Macrossan Depot [11]*

Date	Round	Exposure	Round Temp (°C)	Ambient Temp (°C)
Nov 30	Black	Exposed	66.1	33.8
Dec 4	Olive	Covered	66.6	33.6
Dec 5	Olive	Covered	68.0	33.1
Dec 6	Olive	Covered	67.3	32.1
Dec 8	Olive	Covered	71.2	36.7
Dec 9	Olive	Covered	72.6	38.6
Dec 18	Black	Exposed	65.0	35.4
Dec 19	Black	Exposed	67.3	35.4
Dec 20	Black	Exposed	66.4	35.6
Dec 21	Black	Exposed	66.4	34.7
Dec 22	Black	Exposed	67.6	35.2
Dec 26	White	Covered	67.3	37.0
Dec 27	Olive	Covered	68.1	37.4
Dec 28	Olive	Covered	68.9	38.9
Dec 29	White	Covered	65.1	36.2
Jan 1	Black	Exposed	65.8	35.3
Jan 2	Black	Exposed	69.4	38.1
Jan 3	Black	Exposed	70.8	39.9
Jan 4	Black	Exposed	65.3	35.3
Jan 5	Black	Exposed	65.9	36.1
Jan 16	Black	Exposed	66.3	36.6
Jan 17	Olive	Exposed	66.6	35.6

The maximum recorded 'exposed' temperature of 70.8°C, with a corresponding ambient temperature of 39.9°C, suggests that in the A2 climatic region, materiel temperature rise due to solar radiation can be in excess of 30°C above ambient temperature for the Cartridge 105 mm Tank HESH L35A3.

For category B2 conditions, some trials reported by Redman and McRae [12] included the monitoring of temperatures of inert-filled items exposed in the open air at Innisfail:

The thermocouple which recorded the highest temperatures during this trial was fitted to the motor skin of an unboxed ASROC rocket motor. The highest temperature recorded by this thermocouple was 74°C in February and the thermocouple 1% temperature for the hottest month (January) was 71°C.

Redman and McRae [12] then examined correlations between ambient conditions and rocket motor skin temperatures. Using data only from days of the trial which were clear-sky days, they found that in general, items with high 1% temperatures had high correlation factors and regression coefficients for correlations of the difference between skin and ambient temperatures with solar radiation intensity. This is as expected as a high correlation factor implies that solar radiation is the dominant factor controlling skin temperature. The low absorbence of solar radiation by white surfaces and the consequent small temperature rises means other factors, notably convective cooling will have magnitudes comparable to that of solar radiation and the correlation of temperature rise with solar radiation will be poor. They extended their results to the hottest parts of Australia and, with some assumptions, deduced that with a 1% ambient temperature of 44°C (the maximum temperature in the category A2 operational cycle) the potential maximum skin temperature was about 80°C.

Webb [6] also includes trials results from the manpack radios at Innisfail: four manpack radios were exposed on concrete aprons close to the S280 communications shelter. While the maximum internal radio temperature which was recorded was 59.3°C (for 0.25 hours in the twelve month period), the maximum radio surface temperature recorded was 63°C.

Both DEF (AUST) 5168 and STANAG 2895 give the same diurnal cycles for direct solar radiation, to be applied during operational conditions in categories A2 and B2. For category A2, this varies from 0 to 1120 W/m^2, and for B2 from 0 to 970 W/m^2. Further, DEF (AUST) 5168 includes a solar radiation cycle for category C0(A) conditions, varying from 0 to 600 W/m^2. The upper limit of 1120 W/m^2 for category A2 seems reasonable as this is close to one solar constant (approximately 1.94 gram calories per square centimetre per minute or 1350 W/m^2). Obviously, materiel temperatures attained under these conditions will vary depending on the materiel properties as discussed above.

7. *Discussion and Conclusions*

A number of factors must be considered when discussing the temperature and humidity conditions specified for Australia in the two standards.

Both standards clearly state that the cycles given and the categories allocated to each geographical area are not exact but are to be used as a guide, and where more severe conditions are known to occur these should be used. Following from this, DEF (AUST) 5168 introduced categories B1(A) and C0(A) which have been shown to more accurately represent conditions likely to be experienced in Australia.

Also, neither DEF (AUST) 5168, STANAG 2895 nor QSTAG 360 give precise references for the data used to generate the 1% diurnal cycles, so that no validation of the original data can be attempted.

Notwithstanding these considerations, it is concluded that the A2 and B2 temperature and humidity conditions of both standards, and the B1(A) and C0(A) conditions of DEF (AUST) 5168 reasonably represent operational and storage conditions throughout Australia:

i. The meteorological data which has been examined provides good support for category A2 operational temperature conditions, and the 1% temperature of 44°C closely represents the upper limit of 1% temperatures likely to be encountered in Australia. This finding is based on available meteorological data and areas of central Australia may experience slightly hotter temperatures, however insufficient data is available from these locations. The area over which the A2 operational condition applies is well described by Figure II of DEF (AUST) 5168. The findings of Murrell and McRae [7] suggest that the vapour pressure range quoted for this condition could be expanded slightly, however as temperature and not humidity is recognised as the principal consideration in climatic category A2, this is not considered significant.

ii. The trials data which has been reviewed for category A2 storage conditions also provides reasonable support for the two standards. In [6], ambient temperatures closely approximated the A2 operational conditions, and an approximate 1% storage temperature recorded for the S280 communications shelter was 58°C, which compares reasonably with the A2 storage 1% temperature of 63°C. No evidence of storage conditions in excess of 63°C has been found.

iii. Available meteorological data from Darwin, Thursday Island, Cairns and Townsville also provides good support for the operational temperature and humidity conditions of category B2 (1% temperature of 35°C), with 1% temperatures at these locations varying from 32°C to 35°C.

iv. Trials data from reference [6] suggests that in conditions where the ambient air temperatures closely match the B2 operational condition, storage temperatures may be somewhat lower than the 63°C limit of the two standards. This is to be expected, given that lower air temperatures and solar radiation levels prevail in regions described by category B2 operational conditions than A2 operational conditions and yet the storage cycles for the two categories are put equal. However the difference is not considered to be of practical significance since materiel for Australian deployment would be in any case required to withstand category A2 storage conditions, and the emphasis in category B2 is on the combined effects of temperature and humidity.

v. Although no data was located for direct comparison with category B1 or B1(A) operational conditions, the temperature and humidity cycles quoted seem reasonable. The use of the category B1(A) cycle is recommended over category B1: parts of the B1 requirements are satisfied by the diurnal cycle of category B2, and the B1(A) cycle is more severe and supposedly more representative of Australian conditions than the remaining requirements of category B1.

vi. Category B1 and B1(A) storage conditions are put equal to the operational conditions, because of the negligible effect of solar radiation in these categories. Hence no additional testing is required over the operational condition.

vii. The category C0 cycle is significantly more severe than any conditions experienced in Australia, and for materiel for use in Australia only, design and testing to category C0(A) is more appropriate. This category closely represents conditions experienced at Bathurst and Canberra, and since it is extremely unlikely that military materiel in Australia will be exposed to operational conditions as severe as those at Kiandra (elevation 1395 m), meteorological data available provides good support for the C0(A) cycle as defined.

Values for temperature and humidity at altitude are given in both standards: these have not been considered here. In addition to temperature and humidity, a number of other climatic factors associated with each category can be identified, including wind, ozone, hail, rain, blowing sand and dust. These additional factors are also not discussed in this report.

The remaining climatic factor in the two standards which has seemingly received little attention in Australia when developing diurnal cycles for the design and testing of materiel is direct solar radiation. Operational temperatures close to 44°C occur throughout a large portion of the Australian mainland, however the maximum temperature attained by materiel exposed during use at these locations will be dependent on this operational temperature and the magnitude of direct solar radiation at any given time. The increase in surface temperature of an item of materiel in operational conditions due to solar radiation is a function of the materiel properties. Increases in surface temperature of more than 30°C have been recorded, and up to 35°C have been predicted, for a variety of explosives ordnance. In order to more closely represent conditions in the Australian environment, it is *strongly* recommended that the diurnal solar radiation cycles specified in the two standards be included during testing for category A2 and B2 operational conditions, for materiel which is likely to be exposed directly to solar radiation during use by the ADF.

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9. *References*

1. Australian Defence Standard DEF (AUST) 5168 'The Climatic Environmental Conditions Affecting the Design of Military Materiel', February 1982.

2. NATO Standardization Agreement STANAG 2895 'Extreme Climatic Conditions and Derived Conditions for use in Defining Design/Test Criteria for NATO Forces Materiel', February 1990.

3. 'A Comparison of the Climate at Cloncurry with the Standard Climate of QSTAG 200 (A2)', J. A. McRae, Department of Supply, Australian Defence Scientific Service, Defence Standards Laboratories, Report 554, June 1974.

4. 'High Temperatures in Australia', Maureen E. Redman and J. A. McRae, Department of Supply, Australian Defence Scientific Service, Defence Standards Laboratories, Report 625, April 1975.

5. 'Climatic Averages Australia', (Metric Ed), Bureau of Meteorology, Melbourne, Victoria, 1974.

6. 'Report on Analysis of North Queensland Exposure Data for S280 Shelter and Manpack Radios', N. Webb, Engineering Development Establishment Publication EDE 14/88.

7. 'Climatic Conditions at Air Force Bases in Australia', Barry T. Murrell and John A. McRae, Department of Defence, Materials Research Laboratories, Report MRL-R-787, October 1980.

8. 'The Field Assessment of Smoke Screening Systems, Puckapunyal, November 1986, Part 2 - Effect of Storage conditioning on Grenade Performance', R. J. Hancox, B. Whiffen and F. Fitzsimmons, Department of Defence, Materials Research Laboratories, Report MRL-R-1115, May 1988, (C).

9. Letter Squadron Leader J. M. Gnezdiloff, 1CAMD, to L. Barrington, Explosives Ordnance Division - Salisbury, 1CAMD/517/5/5/ARM Pt 1 (12), 6 April 1992.

10. 'Effects of Solar Radiation on Ammunition', Australian Ordnance Council Proceeding 14/83, 12 July 1983.

11. 'Solar Radiation of 105 mm Tank HESH Ammunition', Department of Defence Directorate of Trials, Defence Trails Report No 6/430, September 1982.

12. 'Temperatures of Ordnance Equipment Exposed at Innisfail, Queensland', Maureen E. Redman and J. A. McRae, Department of Defence, Materials Research Laboratories, Report MRL-R-672, September 1976.

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A review of land surface temperature and humidity conditions specified for Australia in DEF (AUST) 5168 and STANAG 2895

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Solar Radiation	Environmental Conditions	

ABSTRACT

Australian Ordnance Council (AOC) Task 154 "Definition of the Australian Environmental Conditions Affecting the Design of Military Materiel" was accepted by the Explosives Environmental and Service Life Advisory Committee (EESLAC) in 1990 to provide a concise definition of the possible manufacture to target environments to which materiel designed for the ADF could be exposed. This task was divided into two discrete areas of work by EESLAC, namely a study of surface transport vibration levels and a comparative analysis of available meteorological data and the contents of DEF (AUST) 5168. This paper discusses the latter analysis, expanded to include a review of STANAG 2895 also.

In general, the available data suggests that the operational and storage diurnal cycles defined in the two standards reasonably represent the conditions likely to be experienced in Australia. However, the effects of direct solar radiation on materiel must also be considered in determining the maximum temperature which the materiel surface is likely to attain.

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UNCLASSIFIED

A Review of Land Surface Temperature and Humidity Conditions Specified for Australia in DEF (AUST) 5168 and STANAG 2895

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